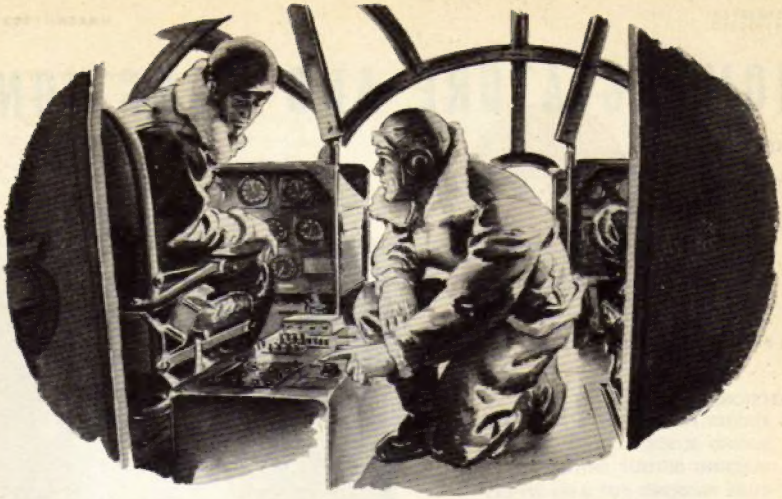


SECTION 5

C-1 AUTOPILOT . . .

The C-1 autopilot automatically controls the airplane in straight and level flight, or maneuvers it in response to the fingertip control of the pilot or bombardier.

The precision of even the most skillful human pilot is limited by his reaction time. Reaction time in turn varies with fatigue, inability to detect deviations the instant they occur, errors in judgment, and muscle coordination.

The autopilot, on the other hand, detects flight deviations the instant they occur, and just as instantaneously operates the controls to correct them. When properly adjusted, the autopilot neither overcontrols nor undercontrols the airplane, but keeps it flying straight and level with all three control surfaces operating in proper coordination.

You must know how to preflight, engage, and adjust your autopilot. You will be able to perform these operations more thoroughly if you also learn the functioning of its various units. Then, when maladjustments occur, you will know how to correct them.

No longer does anyone deny that use of the autopilot greatly improves bombing accuracy.

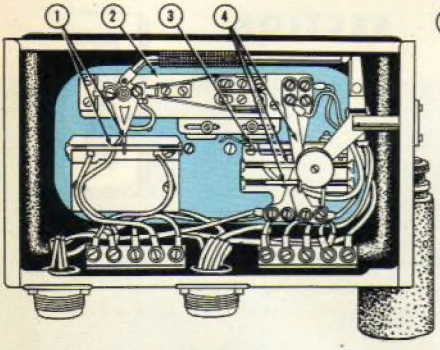
NOMENCLATURE AND FUNCTIONING

STABILIZER

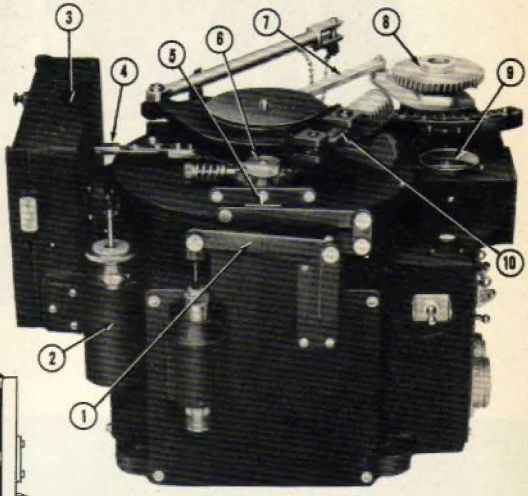
1. DIRECTIONAL ARM LOCK
2. DASHPOT
3. DIRECTIONAL PANEL
4. DIRECTIONAL PANEL ARM
5. AUTOPILOT CLUTCH ARM EXTENSION
6. AUTOPILOT CLUTCH
7. AUTOPILOT CONNECTING ROD
8. DRIFT GEAR CLUTCH
9. PDI
10. BOMBSIGHT CLUTCH

DIRECTIONAL PANEL

1. RUDDER PICKUP POT AND WIPER
2. SLIDING BLOCK
3. ERECTING CUTOUT SWITCH
4. DUAL BANKING POT AND WIPERS



Stabilizer



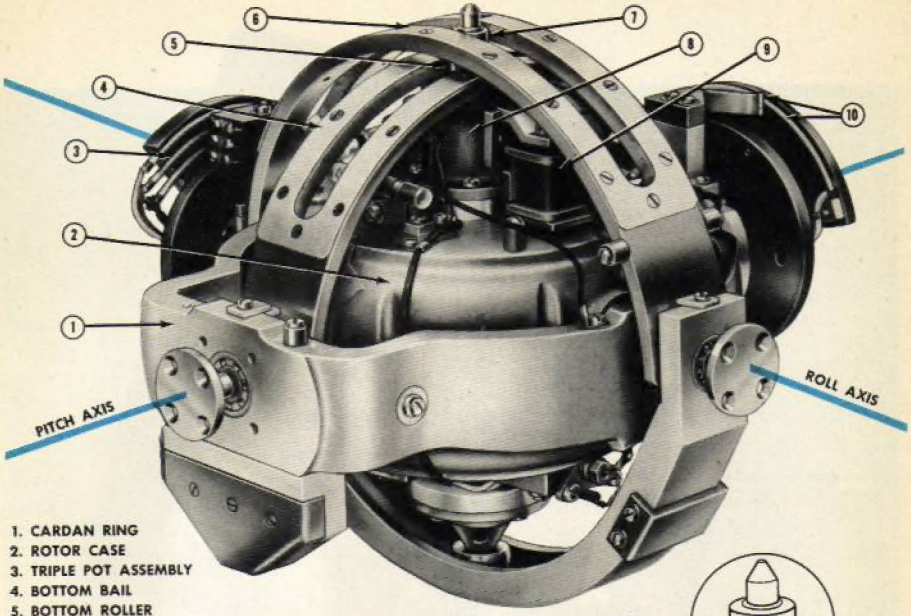
The directional gyro of the bombsight stabilizer detects any deviation of an airplane from **straight** flight. The autopilot clutch connects the directional gyro to the directional panel. The directional panel, attached to the side of the bombsight stabilizer, measures electrically the deviations which the directional gyro notes. Signals then are produced which direct the servo units to correct the deviation.

If you want to steer the airplane by the autopilot clutch, disengage it. This disconnects the directional gyro from the directional panel. Now, you are in control of the directional panel and, through it, you also control the servo units. When you move the autopilot clutch you cause the airplane to turn.

The airplane resumes straight and level flight when you again engage the autopilot clutch to the directional gyro, or when you return the clutch to center by hand.

The directional arm lock prevents the directional panel from cancelling out signals put in by the turn control when you are using it to make a turn. When the turn control is moved from CENTER, the solenoid of the directional arm lock causes the clamping jaws to lock the autopilot clutch arm in position. The autopilot clutch slips throughout the turn. As soon as you put the turn control back in CENTER, the autopilot clutch enables the directional gyro to stabilize the airplane on its new heading.

The dashpot is linked to the mechanism in the directional panel which produces the signal for rudder control. It increases the signal for initial rudder correction as the speed of the airplane's yaw increases. You can govern the extent of increase in that signal by adjusting the knurled nut on top of the dashpot.

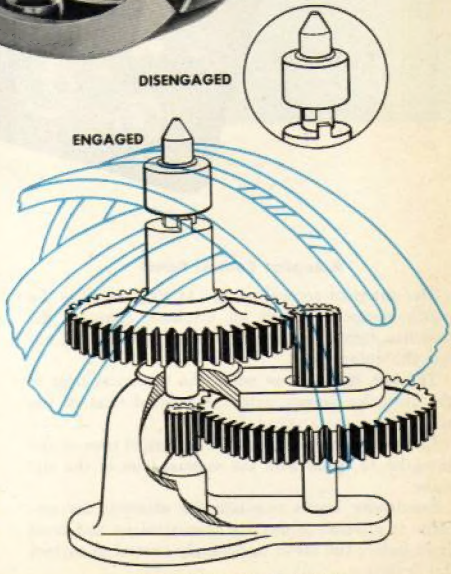


1. CARDAN RING
2. ROTOR CASE
3. TRIPLE POT ASSEMBLY
4. BOTTOM BAIL
5. BOTTOM ROLLER
6. TOP BAIL
7. TOP ROLLER
8. AUTOMATIC ERECTION SYSTEM
9. ERECTING CUTOUT MECHANISM
10. ELEVATOR PICKUP POT AND WIPER

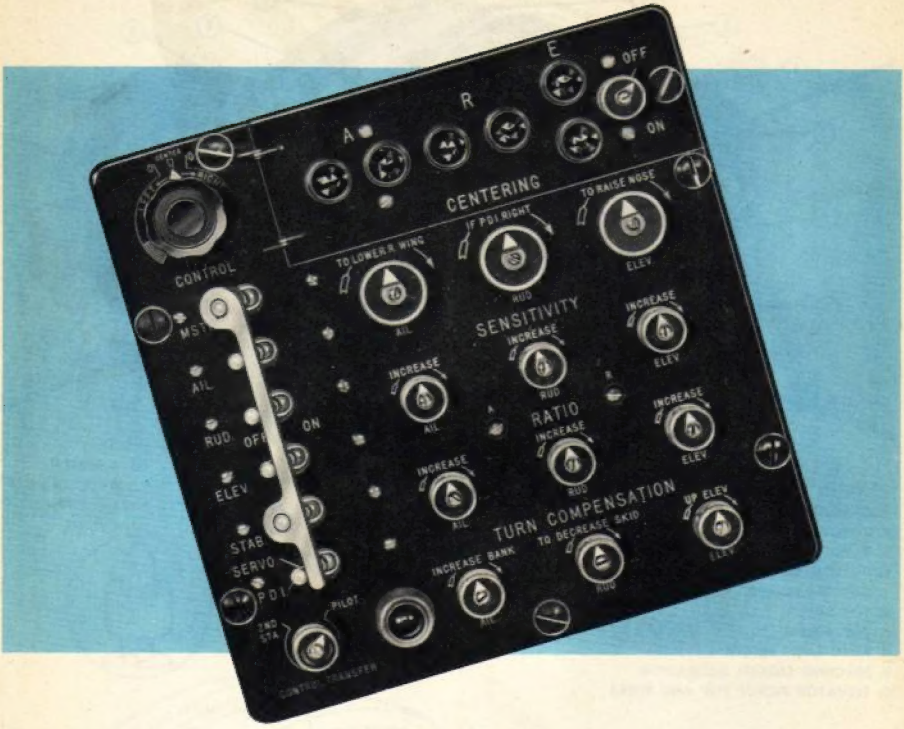
Vertical Flight Gyro

The autopilot's flight gyro detects any deviation of an airplane from **level** flight. It is mounted near the airplane's center of gravity. The flight gyro measures electrically any deviation it picks up. Signals then are produced which direct the servo units to apply control to correct the deviation.

Unless the flight gyro remains vertical, it becomes an inaccurate reference and you no longer can depend on it to maintain the airplane in level flight. Its automatic erection system keeps it constantly in a vertical position, but when this erection system functions while the airplane is in a turn it causes the flight gyro to assume a false vertical. To prevent this, the erection system is automatically disengaged whenever you make a turn control or directional panel turn.



AUTOMATIC ERECTION SYSTEM



Autopilot Control Panel

The autopilot control panel (ACP), located in the pilot's compartment of an airplane, contains the switches, lights, and knobs used to operate and adjust the autopilot.

Tell-tale lights show when the electrical trim of the autopilot agrees with the manual trim of the airplane.

Centering knobs change the electrical trim of the autopilot to agree with the manual trim of the airplane.

Sensitivity knobs regulate the distance the airplane is allowed to deviate from straight and level flight before the servo units apply control to correct the deviation.

Ratio knobs regulate the amount the servo units move the control surfaces for any given deviation of the airplane.

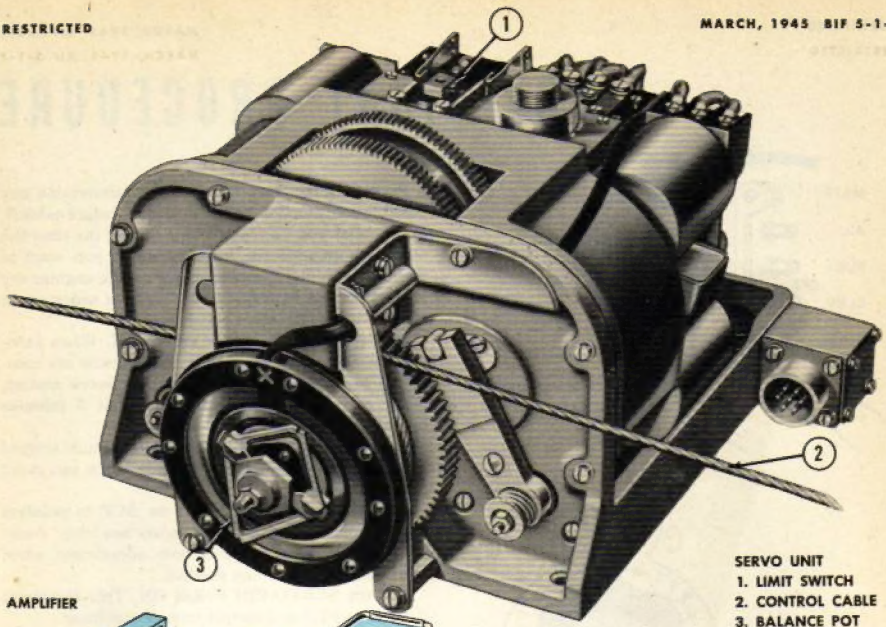
Turn compensation knobs regulate the amount of control necessary when the directional panel is used in making a coordinated turn.

Turn control enables the pilot to make coordinated turns with the autopilot.

Aileron and rudder trimmer screws regulate the amount of aileron and rudder control necessary to make a coordinated turn with the turn control.

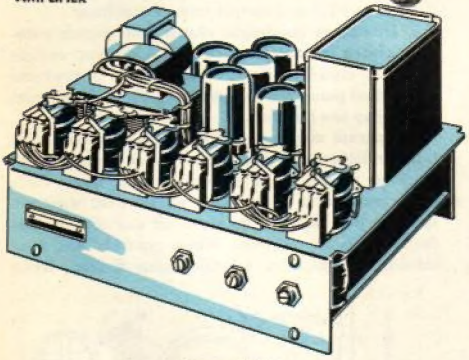
Remote control transfer knob shifts the turn control operation to a remote turn control station in either the bombardier's or navigator's compartment.

Tell-tale light shutter knob regulates the brightness of the tell-tale lights.



SERVO UNIT
1. LIMIT SWITCH
2. CONTROL CABLE
3. BALANCE POT AND WIPER

AMPLIFIER



Servo Units

The servo units provide the mechanical force necessary to move the airplane's control surfaces. There is one servo unit for each control surface and it is located as close as possible to the control surface which it moves. Servo units are connected to control surfaces by cables clamped to the regular control cables of the airplane.

Servo units are so built that they are easily overpowered if, in an emergency, the pilot has to take over control of the airplane himself.

Amplifier

The amplifier is essentially the brains of the autopilot. It receives the electrical signals sent by the other units. It amplifies these signals which direct the proper servo units to apply a definite amount of control in the desired direction.

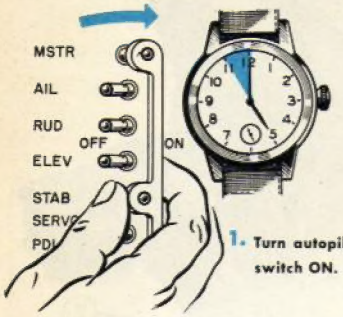
Rotary Inverter

The rotary inverter is a generator which provides the alternating current necessary for the operation of the autopilot. The inverter operates on direct current from the airplane's power supply.

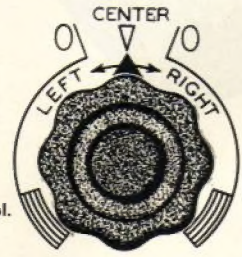
Junction Box

The junction box provides a convenient place to connect the wiring from the various units of the autopilot. As a central wiring station, it saves wire and makes it easier to check the various circuits.

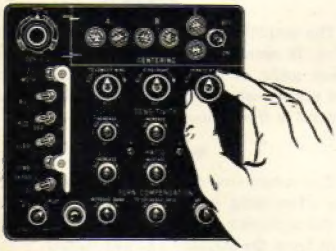
PREFLIGHT PROCEDURE



1. Turn autopilot master switch ON.



2. Center turn control.



3. Turn all adjusting knobs on ACP to pointers up position

4. Turn SERVO-PDI switch ON.

Preflight procedure allows you to determine any possible malfunction of the autopilot before takeoff. It's so brief you can complete it during the time the airplane's engines are warming up. If you want to make this preflight inspection before the engines are started, have a battery cart available in order not to run down the airplane's batteries.

1. **Turn autopilot master switch ON.** When autopilot master switch is turned ON, circuits are completed to directional gyro, amplifier, servo motors, flight gyro, and rotary inverter. **Wait 5 minutes** before turning other switches on.

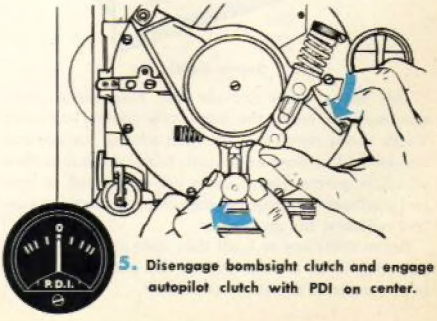
2. **Center turn control.** This prevents turn control from sending signals to servo units when you don't want it to do so.

3. **Turn all adjusting knobs on ACP to pointers up position.** Make sure pointers are not loose. Autopilot should be in approximate adjustment when knobs are at pointers up position.

4. **Turn SERVO-PDI switch ON.** This completes circuits to PDI and torque unit of stabilizer.

5. **Disengage bombsight clutch and engage autopilot clutch with PDI on center.** When you engage autopilot clutch with PDI on center it prevents directional panel from sending signals to servo units when they are not wanted.

6. **Operate airplane controls manually, observing tell-tale lights.** Move control surfaces through their extreme ranges of movement several times. This slides servo unit balance pot wipers over their respective pots and should clean off any dirt or dust that might be on pots. When controls are near streamlined position, tell-tale lights flicker. When



5. Disengage bombsight clutch and engage autopilot clutch with PDI on center.

controls are at extreme ends of their range, lights may go out as pot wipers are moved off pot winding. At any intermediate position one light or other should be on. If lights flicker at intermediate position, corresponding pot needs cleaning. Dirt between wipers and pots causes lights to flicker by breaking contact between wiper and pot.

7. **Turn aileron, rudder, and elevator engaging switches ON, observing tell-tale lights.** As you engage these switches, corresponding lights should come on, flicker, then go out as controls move into streamlined position. At first, lights glow because signals are being sent to restore controls to streamlined position. When servo units move controls to streamlined position signals cease and consequently lights go out.

8. **Rotate each centering knob, observing controls.** Check for proper control movement as you turn each knob clockwise, then counter-clockwise:

Aileron centering knob turned clockwise, control wheel turns right.

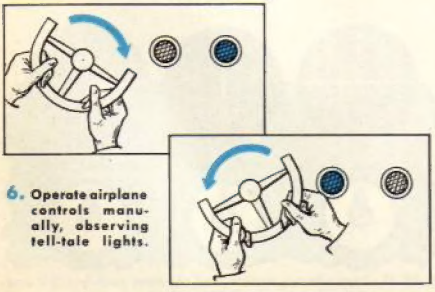
Rudder centering knob turned clockwise, rudder pedal moves forward.

Elevator centering knob turned clockwise, control column moves to rear.

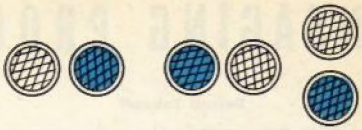
9. **Rotate turn control knob, observing controls.** Check for proper control movement as you turn knob clockwise, then counter-clockwise. When you turn knob clockwise, controls move for right turn.

10. **Disengage autopilot clutch and displace to each side, observing controls. Engage autopilot clutch.** When you displace clutch to left stop, controls should move for right turn.

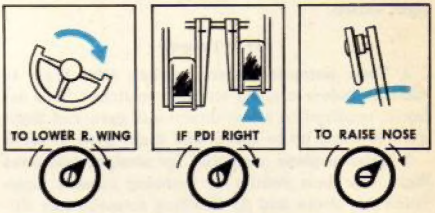
11. **Turn autopilot master switch OFF.** When you turn off master switch, all other switches that engage units of autopilot are turned off. This prevents running down airplane batteries. It also avoids danger of accidental control by autopilot during takeoff.



6. Operate airplane controls manually, observing tell-tale lights.

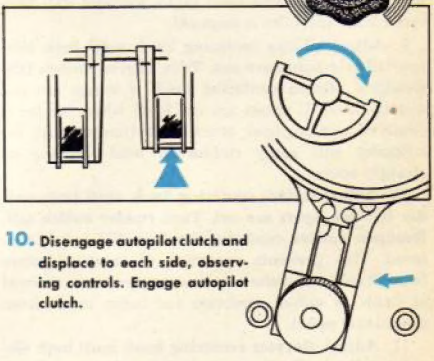


7. Turn aileron, rudder and elevator engaging switches ON, observing tell-tale lights.



8. Rotate each centering knob, observing controls.

9. Rotate turn control knob, observing controls.



10. Disengage autopilot clutch and displace to each side, observing controls. Engage autopilot clutch.

11. Turn autopilot master switch OFF.

ENGAGING PROCEDURE

Before Takeoff

1. **Center turn control.** Also make sure control transfer knob is at PILOT.

2. **Turn adjusting knobs on ACP to pointers up position.** Do this unless knobs are known to be properly adjusted.

3. **Engage autopilot clutch and disengage bombsight clutch.**

After Takeoff

4. **Turn autopilot master switch ON. Wait 10 minutes** before turning on other switches. This delay is required to allow directional gyro and flight gyro to come up to speed, and flight gyro to erect.

5. **Trim airplane manually for straight and level flight.** For best results on bombing mission, open bomb bay doors and fly bombing airspeed and altitude before trimming airplane.

6. **Turn SERVO-PDI switch ON.**

7. **Turn tell-tale light switch ON.**

8. **Center PDI.**

Normal method is to disengage autopilot clutch and center PDI by moving autopilot clutch arm to its center position. Hold PDI centered until autopilot is engaged, then engage autopilot clutch.

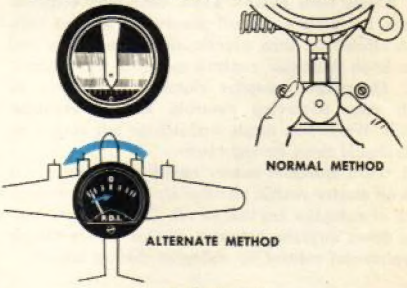
Alternate method is for pilot to center PDI by turning airplane in direction of PDI needle. He then resumes straight and level flight, keeping PDI centered until autopilot is engaged.

9. **Adjust aileron centering knob until both aileron tell-tale lights are out. Turn aileron switch ON. Readjust aileron centering knob** if wings are not exactly level. If wings are not level when rudder is centered and engaged, cross control may result, for autopilot will apply rudder to hold airplane on straight course.

10. **Adjust rudder centering knob until both rudder tell-tale lights are out. Turn rudder switch ON. Readjust rudder centering knob** if PDI is not centered. This prevents operation of erection cutout from directional panel. It also assures same amount of bank in either direction for turns made from directional panel.

11. **Adjust elevator centering knob until both elevator tell-tale lights are out. Turn elevator switch ON. Readjust elevator centering knob** if airplane does not maintain level flight.

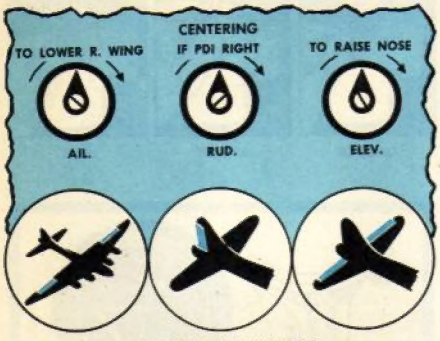
5. Trim airplane manually for straight and level flight.



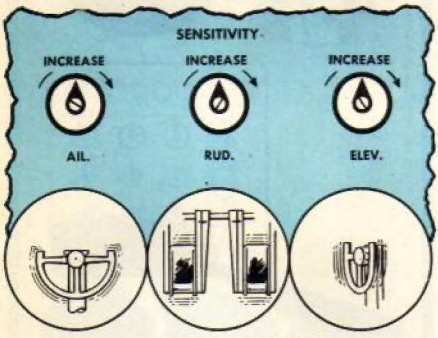
8. Center PDI.

9.-10.-11. Turn aileron, rudder, and elevator switches ON and adjust for straight and level flight.

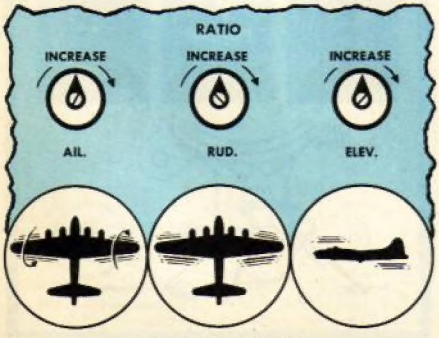
FLIGHT ADJUSTMENTS



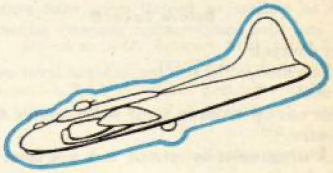
CENTERING ADJUSTMENT



SENSITIVITY ADJUSTMENT



RATIO ADJUSTMENT



Centering

Centering knobs on the ACP are comparable to the trim tabs of the airplane. When flying under autopilot control, use centering knobs instead of mechanical trim tabs to compensate for slight changes in airspeed, center of gravity, or gross weight. When large changes in these flight conditions occur, you must disengage autopilot, re-trim mechanically and re-engage the autopilot. Never trim controls with mechanical trim tabs while autopilot is in operation. In this situation the trim tabs will not change the airplane's attitude because the autopilot counteracts their effect. If you were to move the trim tabs while the autopilot is engaged, and were to leave them in a changed position, when you disengaged the autopilot the trim tabs would suddenly become effective and produce a violent reaction.

Sensitivity

A pilot may apply a correction for even the slightest deviation (high sensitivity) or he may wait for a larger deviation before applying the correction (low sensitivity). High sensitivity provides maximum flight stability but it is possible to adjust sensitivity so high that the controls vibrate or chatter. To adjust sensitivity, turn knobs clockwise until controls chatter. Then turn them counter-clockwise until continuous chatter stops.

Ratio

A pilot may apply too much control in correcting a given deviation, thus causing overcontrol (high ratio), or he may apply too little control in correcting the deviation and produce too slow a recovery (low ratio). To adjust ratio, first turn knobs clockwise to produce overcontrol. Then, reduce ratio to retain quick recovery without overcontrol.

Ratio requires slight readjustment with any appreciable change of indicated airspeed. After any change of ratio, re-check centering.

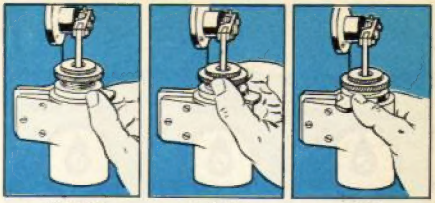
Dashpot

Incorrect dashpot adjustment can cause the airplane to wallow or fishtail even with sensitivity, ratio, and turn compensation properly adjusted. To adjust dashpot:

Unlock dashpot by turning lock nut lever counterclockwise.

Turn nut up or down until wallowing or fishtailing ceases.

Lock adjustment by turning lock nut lever clockwise.



Turn Compensation

Make sure airplane is flying straight and level with proper adjustment of sensitivity and ratio. Then adjust turn compensation knobs in following manner:

Disengage autopilot clutch and move clutch arm slowly to extreme right or left.

Adjust aileron compensation knob to produce 18° bank, as indicated by artificial horizon.

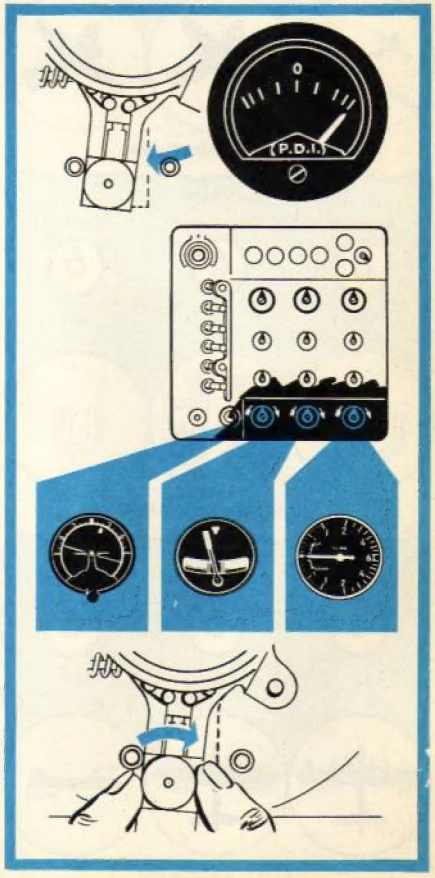
Adjust rudder compensation knob for correct amount of rudder, no skid or slip, as indicated by inclinometer.

Ball must be in exact center.

Make final adjustments with both knobs to obtain perfectly coordinated turn with 18° bank.

Adjust elevator compensation knob to apply sufficient up-elevator to maintain altitude during turn.

Engage autopilot clutch at its extreme position and allow directional gyro to center PDI. This provides a check on the aileron ratio adjustment. If the wings level off too soon and the PDI stops short of center, the aileron ratio is too high. If the wings level off too slowly and the PDI overshoots center, the aileron ratio is too low.



Turn Control

The turn control seldom requires readjustment unless there is reason to believe that a previous adjustment has been changed. Before turning airplane with turn control, be sure airplane is flying straight and level with PDI at center. Rotate turn control knob slowly in direction of turn until pointer reaches lined region of dial or until you feel distinct resistance to further rotation.

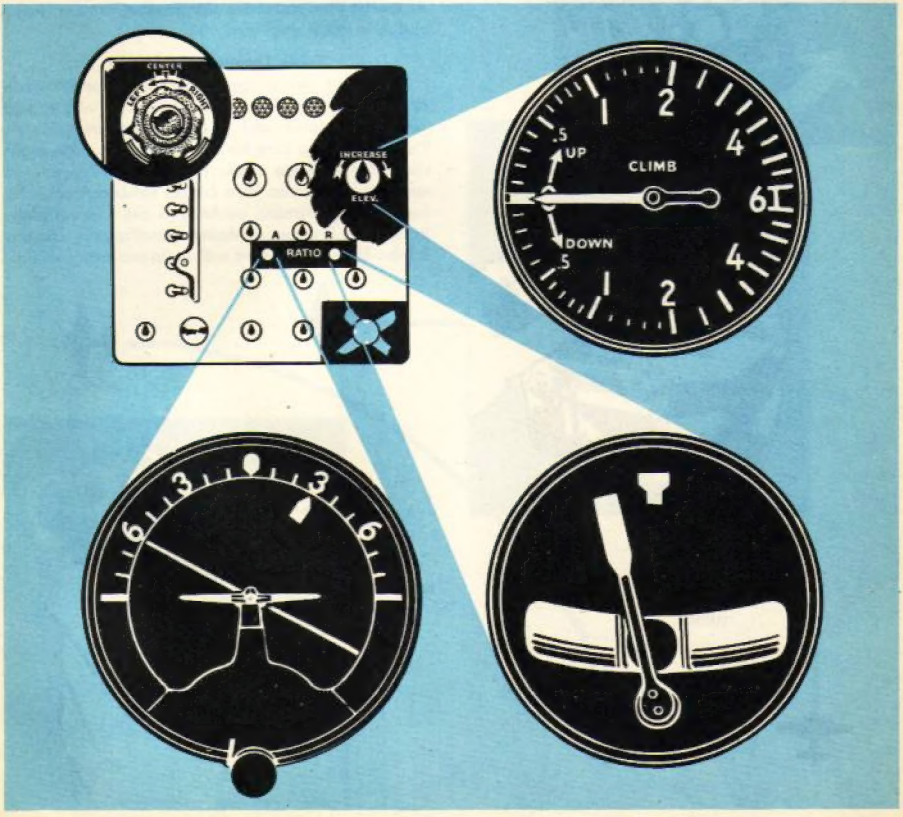
At this setting the airplane should be in a coordinated 30° bank. If it is not, adjust turn control trimmers as follows:

Adjust aileron trimmer on autopilot control panel until artificial horizon indicates 30° bank.

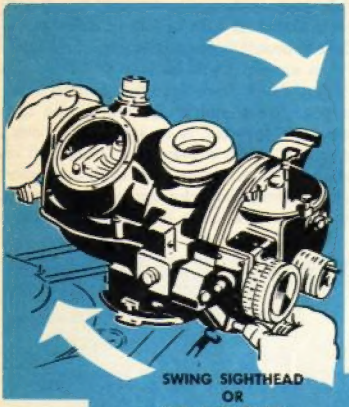
Adjust rudder trimmer until inclinometer indicates perfectly coordinated turn.

Adjust elevator centering knob until climb-and-dive indicator shows no gain or loss in altitude.

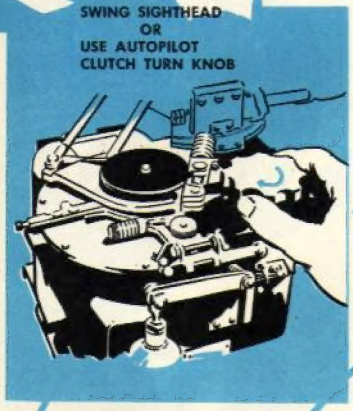
As airplane approaches desired new heading, slowly rotate turn control knob back to 0°. Time this return so pointer will reach 0° when desired heading is attained. (No signal is applied by the turn control when the pointer is at either 0° mark.) Hold pointer at 0° until airplane has leveled off on its new heading. Then center turn control pointer. If elevator centering was changed while in turn, readjust to maintain altitude while in level flight.



DIRECTIONAL PANEL TURNS



SWING SIGHTHEAD
OR
USE AUTOPILOT
CLUTCH TURN KNOB



MANUAL
TURNS

BOMBSIGHT
TURNS

Manual Turns

When you want to turn airplane by means of autopilot clutch, disengage both it and bombsight clutch. Then, displace autopilot clutch either with autopilot clutch turn knob or by swinging bombsight. Smooth displacement produces smooth turn. When you move autopilot clutch to left, airplane turns to right, and vice versa. As airplane comes on desired heading, engage autopilot clutch or bombsight clutch and directional gyro will cause airplane to resume level flight. Autopilot then maintains this heading until autopilot clutch is again displaced.

Turns Through Bombsight

Bombsight course knobs control autopilot when on bombing run. To arrange this, you must engage bombsight clutch and disengage autopilot clutch. Then, when you turn both or either of course knobs clockwise airplane turns right. Bank depends on speed at which you turn course knob or knobs. By continuously turning knobs, you can keep airplane in turn. As it comes on desired heading, stop turning knobs. Directional gyro will maintain new heading.

MALADJUSTMENTS
AND HOW TO CORRECT THEM

PDI CENTERED, BALL NOT CENTERED, IN STRAIGHT FLIGHT

BALL CENTERED, BUT PDI OFF

OVERCONTROL IN RUDDER AXIS

TURNS COORDINATED IN ONE DIRECTION ONLY

LOSS OR GAIN OF ALTITUDE

1. **PDI centered, ball not centered, in straight flight.** This condition is the result of improper trimming, or centering with one wing low and opposite rudder applied to keep the airplane from turning. To correct:

Readjust aileron and rudder centering, **or**

Disengage both rudder and aileron switches and center PDI; then adjust centering and engage rudder and aileron switches.

2. **Ball centered, but PDI OFF.** To correct:

Readjust rudder centering, **or**

Disengage both rudder and aileron switches and center PDI; then adjust centering and engage rudder and aileron switches.

3. **Overcontrol in rudder axis.** This is caused by improper setting of ratio or dashpot. To correct:

Loosen locking collar and unscrew dashpot slowly. Stop when overcontrol ceases, and re-lock.

If loosening dashpot does not eliminate overcontrol, reduce rudder ratio. After changing ratio, check rudder centering and rudder compensation adjustments. Then tighten dashpot to setting just below that which produces overcontrol.

4. **Turns coordinated in only one direction.** This occurs when airplane is not properly trimmed before starting turns. To correct:

Return to level flight and readjust aileron and rudder centering, **or**

Disengage rudder and aileron switches and re-trim manually before re-engaging.

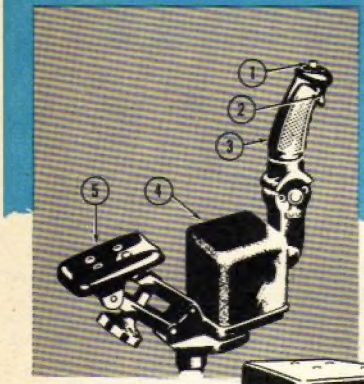
5. **Loss or gain of altitude.**

In straight and level flight, correct with elevator centering knob.

In bombardier's turn, correct with elevator compensation knob and increase elevator ratio.

On bombing run, always maintain altitude with elevator centering knob.

FORMATION STICK



FORMATION STICK AND JUNCTION BOX

1. TRANSFER SWITCH BUTTON
2. TRIGGER SWITCH FOR MICROPHONE
3. GRIP
4. CONTROL MECHANISM
5. ARM REST

The formation stick permits the pilot or copilot to maneuver an airplane quickly though using the autopilot. It gives him, with a minimum of physical effort, the additional control of the airplane necessary for formation flying.

In airplanes equipped with this device, there are 2 formation sticks in the pilot's compartment. One is at the pilot's left, the other at the copilot's right. Only one stick is engaged at a time. A control switch button on top of each stick makes it possible to transfer control from one stick to another.

The extent to which a pilot using the formation stick can control his plane through the autopilot depends on **function selector** setting. For example:

1. When function selector is OFF, autopilot operates normally and formation stick has no control.

2. When the function selector is at ON SERVO BOOST, the formation stick directly controls the servo units of the autopilot. The airplane must then be flown as if it had no autopilot, and as if the formation stick were connected directly to the control cables. The ON SERVO BOOST position is the best setting for the function selector when the airplane is flying in a tight formation and constant maneuvering is necessary.

3. When the function selector is at ON, the stick functions just as the autopilot turn control knob does, except that it provides elevator control as well as aileron and rudder control. This setting is best for lone flying, loose formation flying, or when little maneuvering is necessary.

4. When the function selector is at ON ELEVATOR ONLY, the formation stick controls the attitude of the airplane with respect to the pitch axis only. Moving the stick sideways has no effect on the aileron and rudder controls. This position is used on the bombing run when the pilot wants to use the formation stick instead of the elevator centering knob to control altitude.

The formation stick also has a trigger switch connected in the microphone circuit. It operates whether or not the formation stick or autopilot is engaged. This switch permits the pilot or copilot to use his microphone without releasing formation stick.

Release switches are installed in all airplanes equipped with the formation stick. These switches enable the pilot or copilot to release all three servo units quickly, thereby returning the airplane to manual control. The switches are conveniently mounted on the airplane's control wheels. They are effective whether the formation stick is in use or not.

Caution

Airplane must be level before function selector is turned from one position to another.

PDI must be centered when function selector switch is turned to ON SERVO BOOST.

Autopilot turn control must not be used when function selector switch is at ON SERVO BOOST.